Sutter Basin Pilot Feasibility Study
DRAFT Decision Point #2 Read Ahead

Sutter and Butte Counties, California

FLOOD RISK MANAGEMENT PROJECT

APPENDIX H
ECONOMICS

Economics
Planning Division
Sacramento District

September 2012

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1 Overview

The study area is located in Sutter and Butte Counties, California and is roughly bounded by the Feather River, Sutter Bypass, Wadsworth Canal, Sutter Buttes, and Cherokee Canal. The study area covers approximately 300 square miles and is approximately 43 miles long and 9 miles wide. The study area includes the communities of Yuba City, Live Oak, Gridley, Biggs, and Sutter with a total population of approximately 80,000. Yuba City is the largest community in the study area, with a population of approximately 65,000. A map of the study area can be found in Figure 1-1.

The study area is essentially encircled by project levees of the Sacramento River Flood Control Project and high ground of the Sutter Buttes. In 1917, the Federal government authorized the Sacramento River Flood Control Project, which adopted a system of locally built levees as Federal levees, and constructed additional levees, bypasses, overflow weirs, and pumping facilities. Although the Sacramento River Flood Control Project levees were often constructed of poor foundation materials such as river dredge soils that would not meet today's engineering standards, the levees are relied upon today to provide FRM for numerous communities.

The primary sources of flooding within the study area are the Butte Basin, Sutter Bypass, Feather River, Cherokee Canal, Wadsworth Canal, and local interior drainage. Flood depths and frequency vary throughout the study area. Probability of flooding within the study area is primarily related to the stage of floodwaters within the river channels and the geotechnical probability of levee failure at flood stage.

The Sutter Bypass is a flood control channel approximately three quarters of a mile wide, bordered on each side by levees. The bypass is an integral feature of the Sacramento River Flood Control Project's flood bypass system, conveying flood waters from the Butte Basin, Sacramento River, and Feather River to the confluence of the Sacramento River and Yolo Bypass at Fremont Weir; additional flood flows from the Sacramento River enter the Sutter Bypass through Tisdale Bypass. The lower portion of the Sutter Bypass also conveys water from the Feather River. Within this reach the Feather River is separated from the main conveyance of the bypass by a low levee. This design maintains higher velocities and sediment transport capacity within the Feather River during low flow events while utilizing the large conveyance of the Sutter Bypass during larger events. The Sutter Bypass also receives minor natural flow and agricultural return flow from Reclamation District 1660 to the west and from Wadsworth Canal and DWR pumping plants 1, 2, and 3 to the east. The Sutter Bypass is described by four hydrologic reaches based on tributary inflows: Butte Slough to Wadsworth Canal, Wadsworth Canal to Tisdale Bypass, Tisdale Bypass to Feather River, and Feather River to Sacramento River.

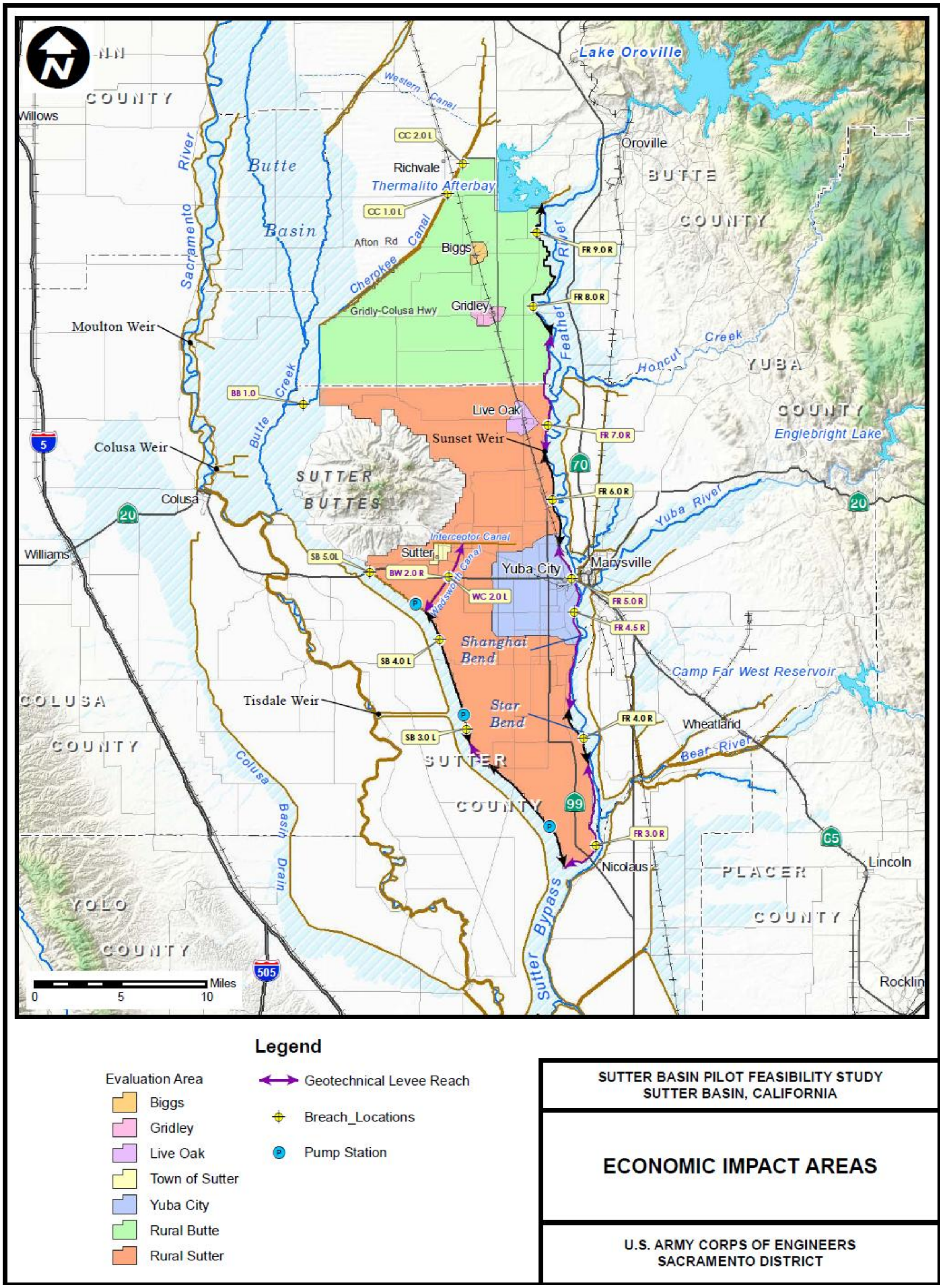
The Feather River is a major tributary to the Sacramento River, merging with the Sutter Bypass upstream from the Sacramento River and Fremont Weir. The Yuba and Bear Rivers are major tributaries to the Feather River. Two major flood management reservoirs are located within the Feather River watershed: Oroville on the Feather River and New Bullards Bar on the Yuba River. The Feather River is described by four hydrologic reaches based on significant inflows:

Thermalito to Honcut Creek, Honcut Creek to Yuba River, Yuba River to Bear River, and Bear River to Sutter Bypass.

The Cherokee Canal is a tributary to Butte Creek and the Butte Basin. The leveed canal was constructed between 1959 and 1960 by USACE. The canal drainage area is 94 square miles and varies in elevation from 70 feet to 2200 feet. The drainage area is bounded by the Feather River watershed to the east and southeast, Butte Creek and its tributaries to the north and west, and by Wadsworth Canal drainage to the south.

The Wadsworth Canal is a leveed tributary to the Sutter Bypass near the town of Sutter. The canal conveys flow from the East and West interceptor canals to the Sutter Bypass. The East and West interceptor canals collect runoff from canals and shallow floodplain runoff into the Wadsworth Canal. The capacity of the East and West Interceptor is limited by levees that are lower than the Wadsworth Canal. As result, inflows to the Wadsworth canal are limited to around 1,500 cfs while excess flows bypass the canal entrance. The design provides resiliency because it reduces the probability that high Wadsworth Canal flows into the Sutter Bypass would combine with high stages in the Sutter Bypass resulting in a possible overtopping failure near the Sutter Bypass and Feather River confluence.

Figure 1-1: Sutter Basin Study Area and Economic Impact Areas



2 Purpose and Scope of Economic Analysis

The purpose of this report is to present the results of the economic analysis performed for the Pilot Feasibility Study of the Sutter Basin. The report documents the existing condition within the study area and proposed alternative plans to improve flood risk management, and designate the tentative National Economic Development (NED) Plan for purposes of estimating federal interest for the Sutter Basin. The report presents findings related to flood risk, potential flood damages and potential flood risk management benefits.

2.1 Methodology

This economic analysis is in accordance with standards, procedures, and guidance of the U.S. Army Corps of Engineers. The Planning Guidance Notebook (ER 1105-2-100, April 2000) serves as the primary source for evaluation methods of flood risk management studies and was used as reference for this analysis. Additional guidance for risk-based analysis was obtained from EM 1110-2-1619, *Engineering and Design – Risk-Based Analysis for Flood Damage Reduction Studies (August 1996)* and ER 1105-2-101, *Planning Risk-Based Analysis of Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies (March 1996)*. Economic evaluation was performed over a 50-year period of analysis. All values are presented in October 2011 price levels, and amortization calculations are based on the Fiscal Year 2012 federal discount rate of 4.0 percent as published in Corps of Engineers Economic Guidance Memorandum (EGM).

3 Floodplain Area and Inventory

3.1 Structural Inventory

A structural inventory was completed based on data gathered from assessor's parcel data and on-site inspection of structures within the flood plain. Structures were determined to be within the economic study area by using Geographical Information Systems (GIS) to compare the 0.2% (1/500) Annual Chance Exceedance (ACE) flood plain boundary (plus a buffer) with the spatially referenced assessor parcel numbers (APN). Information from the assessor's parcel database (such as land use, building square footage, address) was supplemented during field visitation for each parcel within the flood plain by adding fields for foundation height, specific business activity (non-residential), building condition, type of construction, and number of units, for example. Where square footage data was not available, the Google Earth measuring tool was used to estimate square footage. Parcels with structures were categorized by land use and grouped into the following structural damage categories:

1) **Single Family Residential** – includes all parcels represented by a single unit such as detached single family homes, individually owned condominiums and townhouses.
2) **Multiple Family Residential** – includes residential parcels with more than one unit such as apartment complexes, duplexes and quadplex units. Each parcel may have multiple structures.
3) **Commercial** – includes retail, office buildings, restaurants, etc.
4) **Industrial** – includes warehouses, light and heavy manufacturing facilities.
5) **Public** – includes both public and semi-public uses such as post offices, fire departments, government buildings, schools and churches.
6) **Agriculture** – Agricultural inventory was developed using assessor's parcel data and land use codes.

All parcels with structures were assigned to one of the listed categories. Single family and multi-family have been grouped together as "Residential" for presentation purposes.

The without-project damages and with-project benefits are based on potential damages to residential structures and contents, non-residential (commercial, industrial and public) structures and contents, automobiles and agriculture. The study area was divided into seven Economic Impact Areas (EIA's) for purposes of this analysis: Gridley, Biggs, Live Oak, Yuba City, Town of Sutter, Rural Butte and Rural Sutter. The delineation of these impact areas can be found in Figure 1-1.

Structure counts (assuming levee breaches) for a 0.2% (1/500) ACE event are presented by EIA in Table 3-1. Note that the Town of Sutter is not inundated by a 0.2% ACE event.

Table 3-1: Structural Inventory –Existing Conditions
Number of Structures within 0.2% (1/500yr) Annual Chance Floodplain if Levee Failures Occurs

Economic Impact Area	Commerical	Industrial	Public	Residential	TOTAL
Biggs	18	1	0	586	**605**
Gridley	81	7	4	1,931	**2,023**
LiveOak	51	5	23	2,088	**2,167**
Yuba City	872	210	122	18,760	**19,964**
Town of Sutter	0	0	0	0	**0**
Rural Butte	10	16	0	1,242	**1,268**
Rural Sutter	10	29	8	1,162	**1,209**
TOTAL	**1,042**	**268**	**157**	**25,769**	**27,236**

3.2 Value of Damageable Property – Structures and Contents

The value of damageable structures was estimated based on depreciated replacement values. The depreciated replacement value of a structure was determined by multiplying the structure's square footage by the cost per square foot and a remaining-value ratio. Values for cost per square foot were obtained from the Marshall and Swift Valuation Service based on land use, building type, construction class, and quality. The remaining-value ratio was based on the factors such as condition of the structure and the year the structure was built.

The value of damageable building contents was estimated as a percentage of depreciated structure value based on associated land use. Content percentages were based on the expert elicitation findings used in the *American River Watershed Common Features Natomas Basin Post-Authorization Change Report and Interim General Reevaluation Report* (USACE, 2010).

The total value of damageable property (structures and contents) within the Sutter Basin 0.2% (1/500) ACE event is estimated at $6.9 billion. Table 4 displays the total value of damageable property by damage category.

Table 3-2: Value of Damageable Property – Existing Conditions Within the 0.2% (1/500) Annual Chance Floodplain if Levee Failure Occurs

October 2011 Prices ($1,000's)

Economic Impact Area	Commercial		Industrial		Public		Residential		TOTAL	
	Structures	Contents	Structures	Contents	Structures	Contents	Structures	Contents	Structures	Contents
Biggs	3,780	2,829	1,759	601	0	0	49,747	24,873	**$55,286**	**$28,304**
Gridley	37,534	34,694	36,953	14,942	2,175	1,290	191,168	95,584	**$267,830**	**$146,509**
LiveOak	14,621	11,022	1,389	2,269	31,064	10,984	213,262	106,631	**$260,335**	**$130,906**
Yuba City	585,935	468,893	234,644	183,184	239,100	95,338	2,395,719	1,197,860	**$3,455,399**	**$1,945,276**
Town of Sutter	0	0	0	0	0	0	0	0	**$0**	**$0**
Rural Butte	1,659	2,261	32,091	13,571	0	0	133,513	66,756	**$167,262**	**$82,588**
Rural Sutter	3,585	5,436	24,389	15,246	12,868	5,661	183,350	91,675	**$224,192**	**$118,018**
TOTAL	**$647,114**	**$525,135**	**$331,225**	**$229,814**	**$285,207**	**$113,273**	**$3,166,758**	**$1,583,379**	**$4,430,304**	**$2,451,601**

4 Depth-Damage Relationships

Damages to structures and contents were determined based on depth of flooding relative to the structure's first floor elevation. To compute these damages, depth-damage (DD) curves were used. These curves assign loss as a percentage of value for each parcel. The deeper the relative depth, the greater the percentage of value damaged. The sources of the relationships were different depending on land use. For residential structures, the IWR DD curves were used in accordance with EGM-04-01. The non-residential structure DD curves used here were originally developed for the May 1997 "Morganza to the Gulf, Louisiana Feasibility Study." These curves have been used extensively in Sacramento District, including on the American River studies. For Sutter, the long duration versions of the DD curves were used. Depth-damage curves for non-residential contents were taken from the American River Watershed Economic Re-evaluation Report (ERR) expert elicitation for long duration flooding. Depth Damage relationships are shown in the tables below.

Table 4-1: Depth Damage Curves for Residential (Structure and Content)

CATEGORY		DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET							
		-4.0	-1.0	0.0	1	3	5	10	15
1 Story	Structure	0%	3%	13%	23%	40%	53%	73%	80%
	Content	0%	2%	8%	13%	22%	29%	38%	40%
2 Story	Structure	0%	3%	9%	15%	26%	36%	56%	68%
	Content	0%	1%	5%	9%	16%	21%	32%	37%
Split	Structure	0%	6%	7%	9%	17%	29%	63%	84%
	Content	0%	2%	3%	5%	11%	20%	46%	61%
1 Story w/base	Structure	5%	19%	26%	32%	46%	59%	80%	81%
	Content	6%	13%	16%	19%	25%	30%	39%	39%
2 Story w/base	Structure	5%	14%	18%	22%	32%	42%	65%	76%
	Content	5%	10%	12%	14%	18%	22%	34%	49%
Split w/base	Structure	5%	14%	19%	23%	33%	44%	65%	69%
	Content	4%	9%	12%	14%	18%	22%	26%	26%
Mobile Home-Short Duration	Structure	0%	6%	10%	45%	46%	66%	66%	66%
	Content	0%	0%	0%	38%	69%	90%	90%	90%
Mobile Home-Long Duration	Structure	0%	6%	10%	45%	96%	96%	96%	96%
	Content	0%	0%	0%	85%	99%	99%	99%	99%

Table 4-2: Depth Damage Curves for Non-Residential Structures

CATEGORY	DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET						
	-1.0	0	1	3	5	10	15
1 Story Short Duration	0	7	16	28	31	46	50
2 Story Short Duration	0	5	10	18	22	38	38
1 Story Long Duration	0	7	22	31	32	54	86
2 Story Long Duration	0	5	15	22	23	46	80

Table 4-3: Depth Damage Curves for Non-Residential Content 1-story

CATEGORY	DEPTH OF FLOODING ABOVE THE FIRST FLOOR IN FEET						
	-1.0	0	1	3	5	10	15
Food Stores	0	0	78	100	100	100	100
Furniture-Retail	0	0	98	100	100	100	100
Grocery Store	0	0	87	100	100	100	100
Hotel-Full Service	0	0	88	100	100	100	100
Medical	0	0	75	100	100	100	100
Office	0	0	97	100	100	100	100
Restaurant	0	0	91	100	100	100	100
Rest-Fast Food	0	0	88	100	100	100	100
Retail	0	0	80	100	100	100	100
Service-Auto	10	10	74	100	100	100	100
Shopping Centers	0	0	96	100	100	100	100
Heavy	0	0	33	77	100	100	100
Light	0	0	88	99	100	100	100
Warehouse	0	0	84	100	100	100	100
Churches	0	0	73	99	99	99	100
Government	0	0	97	100	100	100	100
Recreation	0	0	98	100	100	100	100
Schools	0	0	88	100	100	100	100
Farms	0	0	56	100	100	100	100

5 Uncertainty and Other Categories

5.1 FLO-2D Grid Cells and Parcel Assignments using GIS

GIS was used to assign centroids to each parcel within the study area and these "points" were then overlaid onto the grid-cells of the FLO-2D model, resulting in the assignment of each parcel (structure) to a specific grid-cell within the hydraulic model. Due to the non-uniform nature of parcel shapes compared to the uniform (i.e. 1000ftx1000ft) nature of the FLO-2D grid-cells, some grid-cells contain zero parcels and other grid-cells have multiple parcels assigned to them. The water surface elevation of the grid-cell now becomes the water surface elevation for all parcels contained therein. Using the grid-cell assignments along with the depths of flooding for the 50% (1/2), 10% (1/10), 4% (1/25), 2% (1/50), 1% (1/100), 0.5% (1/200), 0.2% (1/500) ACE flood events, water surface profiles were developed and imported into HEC-FDA.

5.2 Economic Uncertainty Parameters

Many of the factors that determine flood damages can be represented by a range of values instead of a single number. Errors in measurement, variation in classification and judgment can lead to differences in values. For this study, in accordance with EM 1110-2-1619, uncertainties in the following parameters were considered in the damage estimation:

- Structure Value
- Content Ratio
- Depth-Damage Percentage
- First Floor Elevation (Foundation Height)

Structure values were determined as a function of Marshall& Swift values per square foot, square footage and estimated depreciation. To estimate the mean value of structures, a triangular distribution (minimum, most likely and maximum values) for each of these parameters were set in the model as discussed in detail.

In addition, standard deviations for all 4 variables were used for all land use/structure types within the FDA model and applied during FDA's Monte Carlo simulation of the Expected Annual Damages. These coefficients of variation were based upon @Risk Monte Carlo simulations for representative structures for each damage category and land use type.

Risk and uncertainty was also included in the Depth Damage Percentages for residential structures and contents that were imported into FDA and applied during the Monte Carlo simulations.

Standard Deviation for foundation heights was set equal to 0.5 feet.

5.3 Other Damage Categories

5.3.1 Agricultural Losses

ER 1105-2-100, Appendix E, beginning on page E-113 includes specific guidance for studies where the primary damages occur to agricultural crops. Primary damages in this evaluation focus on the crop damage, loss of stored crops, and loss of farm equipment. These damages are directly related, and evaluated with special consideration for the expected time of seasonal flooding as well as the variability associated with crop prices and yields. The identified hydrologic/hydraulic variables, discharge associated with exceedence frequency and conveyance roughness and cross-section geometry, also apply to agricultural studies.

Based on empirical analyses conducted for past Corps projects, subject matter expertise from the agricultural economist and professional judgment, the project delivery team expects agricultural damages to total 10-15% of total project damages; amounts which are not expected to drive plan selection. A simplified approach was developed for this study based on stage-damage curves for land use types within the study area and simplifying calculations by utilizing 1,000 ft by 1,000 ft hydraulic model grid elements.

Expected Annual Damages associated with Agricultural land uses will be used in the comparison and screening of refined alternatives for the Sutter Basin Feasibility Study. The refined alternatives are presented in Plates 3 through 8. The final array of alternatives (Tentative Selected Plan, National Economic Development Plan, and Locally Preferred Plan) will be selected from these refined alternatives. The final array of alternatives will be evaluated in further detail in the next phase of the study.

A more detailed writeup of the Agriculture analysis is available upon request in a technical memorandum.

5.3.2 Automobile Losses

Losses to automobiles were determined as a function of the number of vehicles per residence, average value per automobile, estimated percentage of autos removed from area prior to inundation, and depth of flooding above the ground elevation. Depth-damage relationships for autos were taken from EGM 09-04 and modified based on weighted average of distributions of car types (SUV, truck, sedan, sports car, etc) in California. Damages for autos begin once flood depth has reached 0.5 feet, and this damage curve can be seen in Table 5-1. Vehicle counts were estimated using an assumption of 2 vehicles per residential structure. Evacuation (autos moved out of the flooded area) was assumed to be 50%, as used on American River and other Corps studies. Depreciated replacement value of autos was based on a price adjusted Bureau of Labor Statistics average used car value of $8,865[1]. Uncertainty was incorporated using a normal distribution and a standard deviation at 15%.

[1] $8,865 was derived from taking a value of $7,988 from the 2010 Natomas PAC and adjusting for price level using CPI for used cars and trucks.

Table 5-1: Automobile Depth Damage Function

Damage Category	Depth in Feet													
	-1	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
	% Damage to Structure/Content													
Automobiles	0	0	3	24	34	43	60	75	86	94	97	99	100	100
Std. Dev	0	0	10	8	7	6	5	3	4	7	7	7	8	8

5.3.3 Emergency Costs, Cleanup Costs, Road Damages and Traffic Disruption

An expert-opinion elicitation panel comprised of professionals having significant, relevant experience in the field of emergency response convened in Sacrament, CA (2009) with the goal of developing estimates of the economic cost associated with various emergency related damage categories (evacuation, debris activities, public services, utilities, etc). Initial model calculations for other district studies, as proportion of structure and content damages, range from 1-3%. Additionally, road damages and traffic-related costs associated with detours and extra time traveled experienced by motorists due to potential flooding in the Sutter Basin was forgone based on prior experiences, which have shown such damage categories to be relatively minimal when compared to structural damages. Nevertheless, it is recognized that in order to detail the magnitude of flooding problems in the Sutter Basin, the economic analyses can be conducted. However, because these damage categories are not expected to drive plan selection, they were omitted from the analysis. If deemed necessary, emergency costs, road damages and traffic disruption analyses can be conducted during refinement of the TSP.

6 Without Project Damages

6.1 HEC-FDA Model

For the Sutter Basin Pilot Feasibility Study, expected annual damages were estimated using the US Army Corps of Engineers, FRM-PCX certified risk-based Monte Carlo simulation program HEC-FDA v. 1.2.5a. Risk is a function of both probability and consequence, and the fact that risk inherently involves chance leads directly to a need to describe and plan for uncertainty. Corps policy has long been to acknowledge risk and uncertainty in anticipating floods and their impacts and to plan accordingly[2]. Historically, that planning relied on analysis of the expected long-term performance of flood-damage reduction measures, application of safety factors and freeboard, designing for worse case scenarios, and other indirect solutions (such as engineering judgment) to compensate for uncertainty. These indirect approaches were necessary because of the lack of technical knowledge of the complex interaction of uncertainties in estimating hydrologic, hydraulic, geotechnical, and economic factors due to the complexities of the mathematics required for doing otherwise. However, with advances in statistical hydrology and the availability of computerized analysis tools (such as HEC-FDA described below), it is now possible to improve the evaluation of uncertainties in the hydrologic, hydraulic, geotechnical, and economic functions. Through this risk analysis, and with careful communication of the results, the public can be better informed about what to expect from flood-damage reduction projects and thus can make more informed decisions. The determination of EAD for a flood reduction study must take into account complex and uncertain hydrologic, hydraulic, geotechnical, and economic information:

- **Hydrologic -** The discharge-frequency function describes the probability of floods equal to or greater than some discharge Q,
- **Hydraulics -** The stage-discharge function describes how high (stage) the flow of water in a river channel might be for a given volume of flow discharge,
- **Geotechnical -** The geotechnical levee failure function describes the levee failure probabilities vs. stages in channel with resultant stages in the floodplain, and
- **Economics -** The stage-damage function describes the amount of damage that might occur given certain floodplain stages.

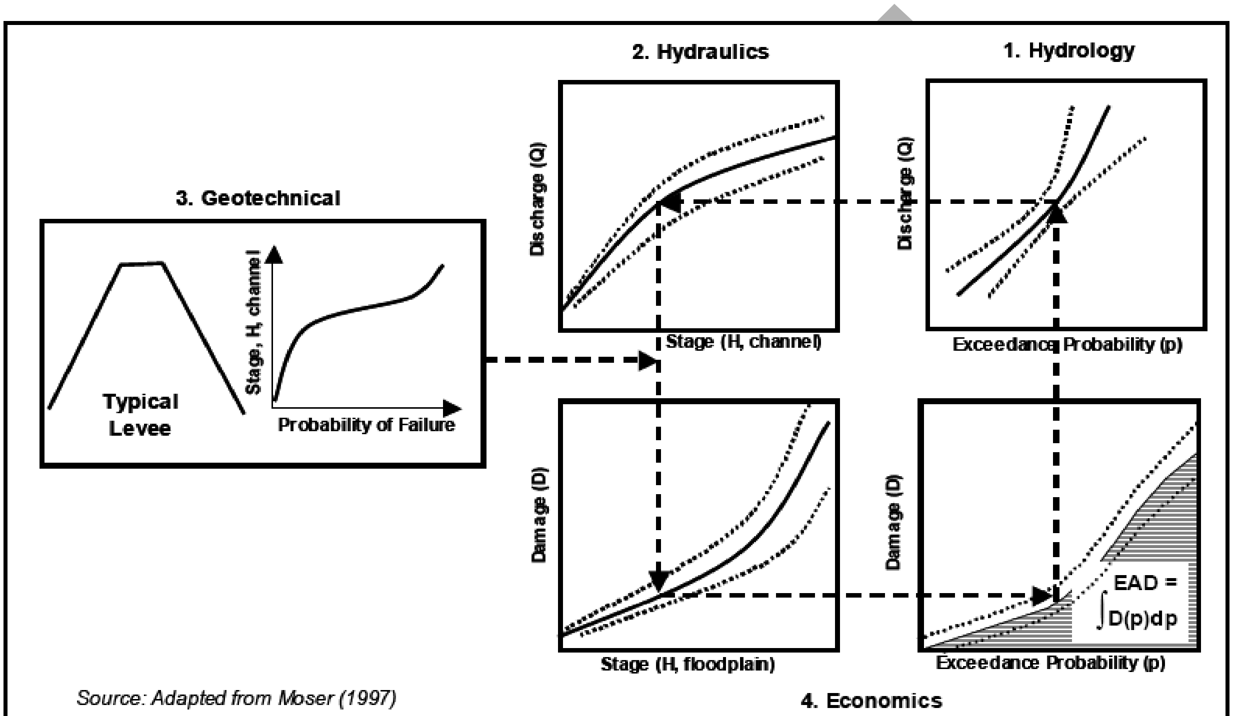
6.2 Estimation of Expected Annual Damages

To find the damage for any given flood frequency, the discharge for that frequency is first located in the discharge-frequency graph (graph #1), then the river channel stage associated with that discharge value is determined in the stage-discharge graph (graph #2). Once the levees fail and water enters the floodplain, the stages (water depths) in the floodplain inundate structures and cause damage (graph #4, left side). HEC-FDA uses a sampling of the curves within the uncertainty bounds of these relationships to generate the probability damage curves used in EAD calculations. By plotting this damage and repeating for process many times, the damage-frequency curve is determined (graph #4, right side). EAD is then computed by finding the area

[2] In a flood risk management study, risk is defined as the probability of failure during a flood event and the resulting consequence. Uncertainty is the measure of the imprecision of knowledge of variables in a project plan.

under the flood damage-frequency curve by integration for the without, interim, and with project conditions. Reductions in EAD attributable to projects are flood reduction benefits. Uncertainties are present for each of the functions discussed above and these are carried forth from one graph to the next, ultimately accumulating in the EAD. These uncertainties are shown in Figure 6-1 as “error bands” located above and below the hydrologic, hydraulic and economics curves.

Figure 6-1: Uncertainty in Discharge, Stage and Damage in Determination of Expected Annual Damages



Some of the important uncertainties specific to the Sutter Basin Feasibility Study include:

- **Hydrologic -** Uncertainty factors include hydrologic data record lengths that are often short or do not exist, precipitation-runoff computational methods that are not precisely known, and imprecise knowledge of the effectiveness of flow regulation.[3]
- **Hydraulics -** Uncertainty arising from the use of simplified models to describe complex hydraulic phenomena, including the lack of detailed geometric data, misalignments of hydraulic structures, debris load, infiltration rates, embankment failures, material variability, and from errors in estimating slope and roughness factors. For all EIA’s a standard deviation in stage of 1.5 feet was used. (EM-1110-2-1619 guidance for minimum uncertainty).

[3] The hydrologic data record lengths (period of record) are the number of years of a systematic record of peak discharges at a stream gage. This parameter directly influences the uncertainty associated with the frequency-discharge function shown in Figure 6-1 and consequently the project performance statistics. In general, a longer period of record implies less uncertainty associated with this function. The period of record used for the Sutter Basin is 94 years.

- **Geotechnical –** Under without project conditions, levee fragility curves were developed and input into HEC-FDA for each of the 15 levee reaches identified in section 6.3 below.
- **Economics -** Uncertainty concerning land uses, depth/damage relationships, structure/content values, structure locations, first floor elevations, the amount of debris and mud, flood duration, and warning time and response of floodplain inhabitants (flood fighting).

6.3 Levee Breach and Floodplain Assignments by Economic Impact Area and Event

As mentioned in section 1, the study area is surrounded by project levees and high ground of the Sutter Buttes. For this study, the existing levees were separated into 15 levee reaches and a representative breach location was chosen for each reach. These breach locations can be found in Figure 1-1. When the study area becomes inundated, the floodwaters flow from north to south and then pool up in the southern portion of the Sutter Basin. Therefore, a breach on the northern section of the Feather River would cause a larger inundation area than a breach on the southern portion, but that does not necessarily mean it has the highest risk (probability & consequence).

For without project conditions, each EIA was assigned a dominating breach location which represents the breach where significant flooding starts to occur. A specific breach location was also assigned to each ACE event floodplain for each EIA based on the worst risk for that particular event by EIA. Risk is a function of both probability and consequence. Determining Breach and Floodplain assignments by EIA and event was a two step process:

1. Probability for floodplain assignments was measured in terms of Annual Exceedance Probabilities (AEP) for each breach location. If an ACE event was close to or lower the breach AEP, then that floodplain was “in play” for consideration. For example, if we are trying to determine which 4% ACE floodplains are “in play” and Breach A has an AEP of 0.1, Breach B has an AEP of 0.37 and Breach C has an AEP of 0.01, then Breach A and Breach B would be considered for Step 2 of the process, while flooding from Breach C would not be considered until looking at the 1% ACE floodplain and lower probability events. AEP for this study are highly dependent on levee fragility curves. A summary of Breach AEP’s and associated levee fragility curves are shown in Table 6-1.

2. Consequence for breach and floodplain assignments was determined based on depth and extent of flooding within each EIA. For each ACE event, those floodplains that were determined to be “in-play” during step one were then compared based on the total number of grid cells inundated and the total depth of flooding within each EIA. The “in-play” breach floodplain that caused the highest total depths and/or the highest number of grid cells inundated was chosen to be used in the water surface profile to be used in HEC-FDA calculation of aggregated stage damage functions. Most of the time the breach with the highest cumulative depth and number of grid cells was the same, but in a few cases where it wasn’t, professional judgment was used and usually the breach with the greater inundation extent was chosen.

The dominating breach and breach/floodplain assignments by ACE event for without project conditions are shown in Table 6-2.

Table 6-1: Levee Breach Location AEP's and Associated Probability-Failure Functions

	Feather River F3.0R	Feather River F4.0R	Feather River F4.5R	Feather River F5.0R	Feather River F6.0R	Feather River F7.0R	Feather River F8.0R	Feather River F9.0R	Cherokee Canal CC01L	Cherokee Canal CC02L	Sutter Bypass SB3.0L	Sutter Bypass SB4.0L	Sutter Bypass SB5.0L	Wadsworth Canal W2.0L	Wadsworth Canal W2.0R
WO Project AEP	**0.0399**	**0.0429**	**0.027**	**0.0417**	**0.0417**	**0.023**	**0.0426**	**0.0426**	**0.2246**	**0.2246**	**0.2962**	**0.2954**	**0.0787**	**0.0683**	**0.4217**
ACE Event:															
50% (1/2)	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.21	0.21	0.06	0.03	0.45
10% (1/10)	0.13	0.15	0.02	0.14	0.14	0.01	0.08	0.08	0.27	0.27	0.35	0.35	0.15	0.10	0.80
4% (1/25)	0.22	0.24	0.09	0.30	0.30	0.18	0.34	0.34	0.32	0.32	0.45	0.43	0.34	0.27	0.86
2% (1/50)	0.26	0.27	0.12	0.34	0.34	0.28	0.34	0.34	1.00	1.00	0.49	0.49	0.49	0.47	0.90
1% (1/100)	0.28	0.29	0.13	0.35	0.35	0.27	0.34	0.34	1.00	1.00	0.55	0.56	0.66	0.68	0.95
0.5% (1/200)	0.35	0.38	0.22	0.56	0.56	0.48	0.51	0.51	1.00	1.00	0.61	0.63	0.84	0.85	0.99
0.2% (1/500)	0.44	1.00	0.47	0.91	0.91	1.00	1.00	1.00	1.00	1.00	0.67	1.00	0.90	1.00	0.99

Table 6-2: Without Project - Levee Breach & Floodplain Assignments by ACE Event and EIA

EIA	Dominating Index Point (Significant Flooding Starts)	FDA Index Point	Annual Chance Exceedance Event						
			50% (1/2)	10% (1/10)	4% (1/25)	2% (1/50)	1% (1/100)	0.5% (1/200)	0.2% (1/500)
Biggs	F9.0R	F9.0R	None	CC.02	F9.0R	F9.0R	F9.0R	F9.0R	F9.0R
Gridley	F9.0R	F9.0R	None	None	F9.0R	F9.0R	F9.0R	F9.0R	F9.0R
Live Oak	F9.0R	F9.0R	None	None	F9.0R	F9.0R	F9.0R	F9.0R	F7.0R
Yuba City	F5.0R	F5.0R	None	S4.0L	F5.0R	F5.0R	F5.0R	F5.0R	F5.0R
Town of Sutter	None	None	None	None	None	None	None	None	None
Rural Butte	F9.0R	F9.0R	None	CC.02	F9.0R	F9.0R	F9.0R	F9.0R	F9.0R
Rural Sutter	S4.0L	S4.0L	None	S4.0L	F5.0R	F5.0R	F5.0R	F6.0R	F6.0R

6.4 Event Damages

Single-event damages for the 50%, 10%, 4%, 2%, 1%, 0.5% and 0.2% ACE flood events were computed in the HEC-FDA model. Floodplains were based upon existing levee's being breached (the levee was modeled with a hole in it at the breach location), which means that the event damage curve, (prior to levee insertion in FDA) may appear relatively flat with high damages beginning at frequent events. This issue it mitigated by the insertion of a levee height and fragility curve into HEC-FDA. The application of the levee fragility curve in FDA truncates the stage damage curve during EAD calculations for those events where a levee failure or overtopping does not occur. The 4% (1/25) and the 0.2% (1/500) annual chance events damages are presented below in Table 6-3 and represent the damages if a levee breach from the dominating breach location by reach were to occur. These damages can be cross-referenced with Table 6-1 and Table 6-2 above to identify the probability of occurrence. For example, Table 6-3 shows Yuba City damages to be $2.2 billion for the 1/25 chance event and $2.8 billion for the 0.2% annual chance event, but these damages have a 30% and 91% chance of occurrence due to a levee failure respectively. The damages listed here represent probability damages prior to the application of economic uncertainty parameters.

Table 6-3: Without Project Probability-Damage Functions (structure and contents) – by EIA
October 2011 Prices ($1,000's), 4.0% Discount Rate

Economic Impact Area	Commercial		Industrial		Public		Residential		TOTAL	
	4% event	0.2% event	4% event	0.2% event	4% event	0.2% event	4% event	0.2% event	4% event	0.2% event
Biggs	3,149	3,717	756	1,131	0	0	17,427	26,861	**$21,332**	**$31,709**
Gridley	40,214	45,079	12,048	14,323	1,759	1,980	29,423	59,634	**$83,445**	**$121,016**
LiveOak	12,925	16,287	2,246	2,645	17,545	23,521	42,675	107,226	**$75,391**	**$149,679**
Yuba City	629,541	737,631	266,963	300,244	177,653	210,395	1,092,447	1,598,342	**$2,166,603**	**$2,846,613**
Town of Sutter	0	0	0	0	0	0	0	0	**$0**	**$0**
Rural Butte	1,805	1,848	8,115	9,328	0	0	24,985	44,594	**$34,905**	**$55,770**
Rural Sutter	4,711	5,165	14,855	28,149	12,415	13,355	72,040	104,439	**$104,021**	**$151,107**
TOTAL	**$692,345**	**$809,727**	**$304,983**	**$355,819**	**$209,373**	**$249,251**	**$1,278,996**	**$1,941,097**	**$2,485,696**	**$3,355,894**

6.5 Expected Annual Damages – Without Project Conditions

The HEC-FDA without project conditions model results (Expected Annual Damages) for structures, contents, automobiles and agriculture are shown, by EIA, in Table 6-4. Total study area without project expected annual damages are approximately $108 million.

Table 6-4: Expected Annual Damages - Without Project Conditions
October 2011 Prices ($1,000's), 4.0% Discount Rate

EIA	Expected Annual Damages (EAD) by Category ($1,000's)						
	Automobiles	Commercial	Industrial	Public	Residential	Agriculture	TOTAL
Biggs	102	90	30	0	554	4	780
Gridley	201	1,149	341	54	1,094	5	2,844
Live Oak	270	366	59	521	1,569	10	2,795
Yuba City	4,050	14,825	6,081	4,025	24,764	269	54,014
Town of Sutter	0	0	0	0	0	0	0
Rural Butte	154	52	263	0	857	1,316	2,642
Rural Sutter	2,218	1,255	6,391	3,790	20,828	10,910	45,392
TOTAL	6,995	17,737	13,165	8,390	49,666	12,514	108,467

6.6 EAD Future Conditions and Equivalent Annual Damages

The without-project equivalent annual damage reflects the damage value associated with the without-project condition over the period of analysis and under changing hydrology, hydraulic (H&H), and economic conditions in the study area. Essentially, equivalent annual damages are expected annual damages that have been converted to a single present worth value and then amortized over the analysis period using the federally mandated discount rate of 4.0%. Existing conditions represent inventory, H&H and geotechnical performance within the study area currently. The future without-project condition is the most likely condition expected to exist in the future in the absence of a proposed water resources project and constitutes the benchmark against which alternatives are evaluated. For the purposes of the identification of the TSP, economics has assumed that future without-project conditions are equal to existing conditions. Once the TSP is identified, the future conditions within HEC-FDA will be set according to the Future Without-Project Conditions portion of the main report. Because any future without project development would take place outside/above the mean 1% annual chance floodplain boundary/WSEL and because any future damages would be discounted back to present value, the future condition is not expected to impact the plan formulation process significantly.

6.7 Project Performance – Without Project Conditions

In addition to damages estimates, HEC-FDA reports flood risk in terms of project performance. Three statistical measures are provided, in accordance with ER 1105-2-101, to describe performance risk in probabilistic terms. These include annual exceedance probability, long-term risk, and assurance by event.

- Annual exceedance probability measures the chance of having a damaging flood in any given year.
- Long-term risk provides the probability of having one or more damaging floods over a period of time.
- Assurance is the probability that a target stage will not be exceeded during the occurrence of a specified flood.

The worst project performance statistics may not necessarily be associated with the breach location producing the most economic damages (as described in section 6.3). For example, both the Feather River and the Sutter Bypass can cause flooding in the Yuba City EIA. Even though the Feather River (F5.0R) causes more significant annual damages in the area, the project performance is worse for the Sutter Bypass. Because economic consequences are higher for the Feather breach, that's what was used in HEC-FDA, but project performance is still limited by the Sutter Bypass. Project performance statistics for each impact area under without project conditions is displayed in Table 6-5 below.

Table 6-5: Project Performance by EIA - Without Project Conditions

Economic Impact Area	Breach Location	Annual Exceedance Probability		Long-Term Risk			Assurance by Event			
		Median	Expected	10 Year Period	30 Year Period	50 Year Period	10%	2%	1%	0.20%
Biggs	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
Gridley	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
Live Oak	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
Yuba City	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
Town of Sutter	None	None	None	None	None	None	None	None	None	None
Rural Butte	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
Rural Sutter	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%

7 With-Project Damages and Benefits

This section will describe how benefits of flood risk management of the final array of alternatives were estimated. Non-monetary outputs such as environmental measures, which may vary for the final array of alternatives, are not included but may factor in the plan formulation decision process.

Benefits were determined by incorporating increments of levee fixes into the FDA model that represent various with-project improvements. Flood risk management benefits equal the difference between the without project damages and the with-project residual damages.

7.1 Conceptual Alternatives

Many conceptual alternatives were considered during the plan formulation process. See the main report for a detailed description of all conceptual alternatives.

7.2 Refined Array of Alternatives

Economic benefits were estimated for each alternative in the Refined Array. The first step was to estimate the maximum economic benefit of fixing all levees to their design height. For each alternative, the benefit was estimated by applying a ratio based on visual inspection of the without and with project floodplains by Hydraulic Design and Economics. Project costs were based on initial parametric project cost estimates (see main report and cost appendix for more detail). These benefits and costs were then compared to screen out those refined alternatives do not appear economically justified even in the most favorable benefit/cost ratio ranges (highest benefit and lowest cost) and/or to compare costs of plans with very similar outputs from a cost effectiveness perspective cost effectiveness. For a more detailed description of this screening, please see the main report. The table below summarizes the findings of the screening. As a result of this screening, only 5 plans (Yuba City Ring Levee, Little J, Minimal Fix-in-Place, Fix in Place Thermalito to Star Bend and Fix-in-Place w/o raising) were carried forward into the Draft Array for identification of the TSP.

Table 7-1: Benefits and Costs for Refined Array of Alternative
October 2011 Prices ($Millions), 4.0% Discount Rate

Alternative	Total First Cost ($Millions)		Annualized Cost ($Millions)		Annual Benefits ($Millions)		Annual Net Benefits ($Millions)		Benefit to Cost Ratio	
	Low	High	Low	High	Low	High	Low	High	Low	High
2.1 - Ring Levees:										
Yuba City	313	671	15	31	12	47	-10	29	0.4	3.2
Gridley	95	204	4	9	1	4	-6	0	0.1	0.9
Live Oak	82	177	4	8	1	3	-5	0	0.1	0.9
Biggs	60	129	3	6	0	1	-5	-2	0.0	0.3
2.2 - Big J	703	1,506	33	70	16	63	-35	26	0.2	1.9
2.3 - Little J	560	1,201	26	56	16	63	-24	32	0.3	2.4
2.4 Minimal Fix in Place	177	381	8	18	5	19	-8	9	0.3	2.3
2.5 Fix in Place Thermalito to Star Bend	422	905	20	42	13	53	-17	29	0.3	2.7
3.1 Fix in Place w/o Raising	737	1,579	34	73	17	68	-36	29	0.2	2.0
3.2 Primarily Fix in Place including modest	882	1,900	41	88	17	68	-48	22	0.2	1.6
4.1 Setbacks with Ecosystem Restoration	1,543	3,308	72	154	17	68	-100	-3	0.1	0.9

7.3 Draft Array of Alternatives – TSP Identification

The draft array of alternatives is listed below. These alternatives were analyzed in more detail to estimate project benefits and identify a TSP. For a detailed description of project measures, please refer to the main report.

SB-1: No Action
SB-2: Minimal Fix-in-Place plus Non-structural
SB-3: Yuba City Ring Levee
SB-4: Little J Levee
SB-5: Fix-in-Place, Thermalito to Star Bend
SB-6: Fix-in-Place, Feather River, Sutter Bypass and Wadsworth Canal
SB-7: Fix-in-Place, Sunset Weir to Laurel Avenue
SB-8: Fix-in-Place, Thermalito to Laurel Avenue

Maps showing the locations of project features for each alternative can be found in Enclosure 3.

7.3.1 With-Project Levee Breach and Floodplain Assignments by Economic Impact Area and Event

With-Project floodplains and index point assignments were done using the same two-step process described in section 6.3 of this report. Without project floodplains were utilized for with-project runs. With-project benefits result from the reduction in flood depths/extents fixed levee reaches are no longer "in play" during water surface profile creation and assignments. With-project levee breach and floodplain assignments by event and EIA can found in Enclosure 4.

Table 7-2 summarizes the levee reach fixes and residual breach locations by alternative.

Table 7-2: Levee Reach Fixes by Alternative

Alternative	Fixed Index Points	Residual Index Points
SB-1: No Action		F3, F4, F4.5, F5, F6, F7, F8, F9, S3, S4, CC1, CC2, W2
SB-2: Minimal Fix in Place	F4.5, F5, F6	F3, F4, F7, F8, F9, S3, S4, CC1, CC2, W2
SB-3: Yuba City Ring Levee	F4.5, F5	*F3, F4, F6, F7, F8, F9, S3, S4,* CC1, CC2, W2[4]
SB-4: Little J Levee	F5, F6, F7, F8, F9	*F3, F4, F4.5, S3, S4*[5], CC1, CC2, W2
SB-5: Fix-in-Place, Thermalito to Star Bend	F4.5, F5, F6, F7, F8, F9	F4, F3, S3, S4, CC1, CC2, W2
SB-6: Fix-in-Place, Feather River, Sutter Bypass and Wadsworth Canal	F3, F4, F4.5, F5, F6, F7, F8, F9, S3, S4, W2	CC1, CC2
SB-7: Fix-in-Place, Sunset Weir to Laurel Ave	F4, F4.5, F5, F6, F7, F8, F9	F3, S3, S4, CC1, CC2, W2
SB-8: Fix-in-Place, Thermalito to Laurel Ave	F4, F4.5, F5, F6, F7, F8, F9	F3, S3, S4, CC1, CC2, W2

[4] For Yuba City Economic Impact Area, only the 500 year residual flooding. All other economic impact areas equal the without project depths and damages.
[5] For F3, F4, F4.5, S3 and S4 residual floodplain depths with the Little J Levee in place were used.

7.3.2 Annual Benefits and Residual Damages

The with-project floodplain and levee assignments described above were then input and run in HEC-FDA to determine residual damages and annual benefits. Residual damages can be found in Table 7-3 and annual benefits can be found in Table 7-4. Residual floodplains for select plans and impact areas can be found in Enclosure 5.

Table 7-3: Residual Annual Damages by Alternative and EIA

October 2011 Prices ($1,000's), 4.0% Discount Rate

Alternative	Expected Annual Damages (EAD) ($1,000's)							
	Biggs	Gridley	Live Oak	Yuba City	Town of Sutter	Rural Butte	Rural Sutter	TOTAL
SB-1: No Action	780	2,844	2,795	54,014	0	2,642	45,392	108,467
SB-2: Minimal Fix in Place	780	2,844	2,795	14,568	0	2,642	32,058	55,687
SB-3: Yuba City Ring Levee	780	2,844	2,795	2,789	0	2,642	45,392	57,242
SB-4: Little J Levee	171	315	381	10,136	0	1,008	31,416	43,427
SB-5: Fix-in-Place, Thermalito to Star Bend	171	318	381	14,568	0	1,008	32,058	48,504
SB-6: Fix-in-Place, Feather River, Sutter Bypass and Wadsworth	171	318	381	2,752	0	1,008	1,589	6,219
SB-7: Fix-in-Place, Sunset Weir to Laurel Ave	780	2,844	2,795	3,694	0	2,642	27,773	40,528
SB-8: Fix-in-Place, Thermalito to Laurel Ave	171	318	381	3,694	0	1,008	27,773	33,345

Table 7-4: Annual Benefits by Alternative

October 2011 Prices ($1,000's), 4.0% Discount Rate

Alternative	Expected Annual Benefits ($1,000's)							
	Biggs	Gridley	Live Oak	Yuba City	Town of Sutter	Rural Butte	Rural Sutter	TOTAL
SB-1: No Action	0	0	0	0	0	0	0	0
SB-2: Minimal Fix in Place	0	0	0	39,446	0	0	13,334	52,780
SB-3: Yuba City Ring Levee	0	0	0	51,225	0	0	0	51,225
SB-4: Little J Levee	609	2,529	2,414	43,878	0	1,634	13,976	65,040
SB-5: Fix-in-Place, Thermalito to Star Bend	609	2,526	2,414	39,446	0	1,634	13,334	59,963
SB-6: Fix-in-Place, Feather River, Sutter Bypass and Wadsworth Canal	609	2,526	2,414	51,262	0	1,634	43,803	102,248
SB-7: Fix-in-Place, Sunset Weir to Laurel Ave	0	0	0	50,320	0	0	17,619	67,939
SB-8: Fix-in-Place, Thermalito to Laurel Ave	609	2,526	2,414	50,320	0	1,634	17,619	75,122

7.3.3 Probability Distribution of Damages Reduced

In accordance with ER 1105-2-101, flood damages reduced were determined as mean values and by probability exceeded. The table below shows the benefits for each alternative for the 75%, 50% and 25% probability that benefit exceeds indicated value. The damage reduced column represents the mean benefits for each increment and the 75%, 50% and 25% represent the probability that the flood damage reduction benefits exceed the number in that column for that increment. For example, Alternative SB-2 has an average (mean) benefit of $50.3 million, but a 50% chance that benefits could be greater than $38.4 million, 75% confidence that benefits will be equal or greater than $24.3 million and 25% confidence that benefits could exceed $72.7 million. This range is the probability distribution of damages reduced and represents the uncertainty in the benefit estimates and incorporates all the uncertainties in hydrology, hydraulics, geotechnical and economics in the HEC-FDA model. The uncertainty in damages reduced should be considered when selecting an optimal plan during the plan formulation process. Judgment should be used to determine if an alternative meets a reasonable level of confidence regarding positive net benefits and identifying if changes in net benefits from alternative to alternative are significant.

Table 7-5: Probability Distribution of Damages Reduced – TOTAL Study Area October 2011 Prices ($1,000's), 4% Interest Rate

Alternative	Annual Damages ($1,000's)			Probability Damage Reduced		
	Without Project	With Project	Damage Reduced	75%	50%	25%
SB-1: No Action	95,954	95,954	0	0	0	0
SB-2: Minimal Fix in Place	95,954	45,686	50,268	24,301	38,376	72,685
SB-3: Yuba City Ring Levee	95,954	44,950	51,004	24,851	40,716	71,125
SB-4: Little J Levee	95,954	34,854	61,100	31,497	46,103	86,746
SB-5: Fix-in-Place, Thermalito to Star Bend	95,954	39,128	56,826	28,627	44,861	81,220
SB-6: Fix-in-Place, Feather River, Sutter Bypass and Wadsworth Canal	95,954	4,287	91,667	45,913	73,277	134,087
SB-7: Fix-in-Place, Sunset Weir to Laurel Ave	95,954	31,296	64,658	31,698	51,348	91,999
SB-8: Fix-in-Place, Thermalito to Laurel Ave	95,954	24,739	71,215	36,024	57,834	100,534

7.3.4 Project Performance

As discussed in Section 6.7, project performance for each alternative is identified by the residual index location that has the highest AEP which causes flooding within an EIA. For many alternatives, the with-project AEP may be the same as the without project AEP, even though the annual damages may decrease significantly. For example, the index point which causes flooding within the Yuba City EIA with the worst AEP is from the Sutter Bypass (S4.0L), even though more significant damages come from a breach on the Feather. Because Alternative SB-2 fixes the stretches of levee on the Feather which cause the worst economic consequence flooding in Yuba City (F4.5R, F5.0R and F6.0R), you see a significant annual benefit from fixing those levees. Although project performance (measured by AEP) has not decreased, the overall consequences of flooding are reduced as levee reaches are fixed. The overall/combined likelihood that the area will get flooded is reduced as levee reaches are fixed. This combined chance of flooding is difficult to quantify, so the representative index point is used.

Project performance statistics for each impact area are displayed by impact area and alternative in the table below.

Table 7-6: Project Performance – With Project Conditions – by EIA

Economic Impact Area	Alternative	Resdiual Breach Location	Annual Exceedance Probability		Long-Term Risk			Assurance by Event			
			Median	Expected	10 Year Period	30 Year Period	50 Year Period	10%	2%	1%	0.20%
Biggs	SB-1: No Action	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-2: Min FIP	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-3: Yuba City Ring	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-4: Little J	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-5: FIP Therm to Star	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-6: FIP ALL	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-7: FIP Sunset to Laurel	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-8: FIP Themalito to Laurel	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
Gridley	SB-1: No Action	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-2: Min FIP	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-3: Yuba City Ring	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-4: Little J	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-5: FIP Therm to Star	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-6: FIP ALL	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-7: FIP Sunset to Laurel	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-8: FIP Themalito to Laurel	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
Live Oak	SB-1: No Action	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-2: Min FIP	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-3: Yuba City Ring	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-4: Little J	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-5: FIP Therm to Star	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-6: FIP ALL	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-7: FIP Sunset to Laurel	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-8: FIP Themalito to Laurel	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
Yuba City	SB-1: No Action	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-2: Min FIP	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-3: Yuba City Ring	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-4: Little J	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-5: FIP Therm to Star	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-6: FIP ALL	F4_0R-fixed	0.0022	0.0022	2%	7%	11%	99%	99%	99%	55%
	SB-7: FIP Sunset to Laurel	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-8: FIP Themalito to Laurel	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
Town of Sutter	ALL	None	None	None	None	None	None	None	None	None	None
Rural Butte	SB-1: No Action	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-2: Min FIP	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-3: Yuba City Ring	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-4: Little J	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-5: FIP Therm to Star	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-6: FIP ALL	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
	SB-7: FIP Sunset to Laurel	F9.0R	0.0386	0.0426	35%	73%	89%	89%	60%	56%	19%
	SB-8: FIP Themalito to Laurel	F9.0R-fixed	0.0022	0.0022	2%	6%	10%	99%	99%	100%	55%
Rural Sutter	SB-1: No Action	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-2: Min FIP	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-3: Yuba City Ring	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-4: Little J	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-5: FIP Therm to Star	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-6: FIP ALL	F4_0R-fixed	0.0022	0.0022	2%	7%	11%	99%	99%	99%	55%
	SB-7: FIP Sunset to Laurel	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%
	SB-8: FIP Themalito to Laurel	S4.0L	0.2482	0.2954	97%	99%	99%	60%	57%	50%	24%

8 Net Benefit Analysis

With benefits calculations complete, annual costs need to be derived to complete the benefit cost analysis. Economic feasibility and project efficiency are determined through benefit cost analysis. For a project or increment to be feasible, benefits must exceed costs and the most efficient alternative is the one that maximizes net benefits (annual benefits minus annual costs). The National Economic Development Plan (NED) is identified as the plan that reasonable optimizes the net benefits.

8.1 Net benefit and BCR uncertainty and ranges

Error! Reference source not found. below summarizes the Net Benefits and Benefit-to-Cost ratio ranges for each of the draft array of alternatives. The low annual benefit represents the 75% confidence (that benefits will exceed the indicated value), the mid represents the 50% and the high annual benefit represents the 25% confidence level. The low annual cost represents the 20% confidence (that costs will be less than the indicated value), the mid annual cost represents the 50% confidence and the high cost represents the 80% confidence. Net Benefit and BCR mean values and ranges were calculated in a Monte-Carlo simulation using a triangular distribution in the annual benefits and the annual costs. The mean Net Benefit and BCR represent the mean result from this Monte Carlo simulation. The low to high range represent the 90% confident range (5%-95%), given our inputs (less than 90% overall because inputs did not represent the 100% range). In other words, we are most confident that Net Benefits and BCR will exceed the low values and become less confident as you move toward the high values, with the best estimate being the mean values.

More detailed costs estimates will be developed for the final array of alternatives (the TSP, NED and Locally Preferred Plan).

Table 8-1 Notes:

1 Cost Range: Min= 20% Mid=50% Max= 80% (confidence costs are less than given value)
2 IDC based on equal annual spending over the following construction schedules: SB-2 = 3years, SB 3 = 5 years, SB-4 = 5 years, SB-5 = 5 years, SB-6 = 7 years, SB-7=4 years, SB-8=6 years
3 First Costs plus IDC amortized over 50 years at 4% plus annual O&M. Annual O&M costs: SB-2 = $195k, SB-3 = $270k, SB-4 = $477k, SB-5 = $360k, SB-6 = $661k, SB-7 = $350k, SB-8 = $500k
4 Benefit Range: Min=75% Mid=50% Max=25% (confidence benefits are greater than given value)
5 Values are a result of Monte Carlo simulations using triangular distributions of annual benefit and annual cost confidence intervals as inputs. Mean=Mean result from simulation.

Table 8-1: Net Benefits and Benefit-to-Cost Ratios – Draft Array of Alternatives in October 2011 Prices ($Million), 4% Interest Rate

Alternative	Total First Cost[1]			IDC[2]	Annualized Cost + O&M[3]			Annual Benefits[4]			Annual Net Benefits[5]			Benefit to Cost Ratio[5]		
	Low	Mid	High	Mid	Low	Mid	High	Low	Mid	High	Low	Mean	High	Low	Mean	High
SB-1: No Action	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0
SB-2: Minimal Fix in Place, Sunset Weir to Star Bend	290	319	361	26	15	16	18	24	38	73	14	29	47	1.8	2.7	3.9
SB-3: Yuba City Ring Levee	411	451	507	57	22	24	27	25	41	71	7	21	39	1.3	1.9	2.6
SB-4: Little J Levee	729	798	899	101	39	42	48	31	46	87	-5	12	33	0.9	1.3	1.8
SB-5: Fix-in-Place, Thermalito to Star Bend	549	608	694	77	29	32	37	29	45	81	2	19	39	1.1	1.6	2.2
SB-6: Fix-in-Place, Feather River, Sutter Bypass and Wadsworth Canal	1,018	1,131	1,297	196	56	62	71	46	73	134	-7	21	55	0.9	1.3	1.9
SB-7: Fix-in-Place, Sunset Weir to Laurel Ave	386	423	479	44	20	22	25	32	51	92	17	36	59	1.7	2.6	3.6
SB-8: Fix-in-Place, Thermalito to Laurel Ave	645	713	812	107	35	39	44	36	58	101	5	26	50	1.1	1.7	2.3

9 Conclusions

The Tentatively Selected Plan will be determined based upon NED and the evaluation of other metrics developed for the Sutter Basin, such as critical infrastructure, life safety and wise use of floodplains. For detailed discussion of these metrics and the identification of the TSP, please refer to the main report.